Hale School
Year 12 Examination
Semester 1, 2020

Write your name below:

Yr12 ATAR CHEMISTRY
UNIT 3

Circle your teacher's initials:

JWZ PRB KF AD

TIME ALLOWED FOR THIS PAPER

Reading time before commencing: Ten minutes
Working time for paper: Three hours

For Examiners only	
Section 1	
Section 2	
Section 3	
Total	

MATERIAL REQUIRED/RECOMMENDED FOR THIS PAPER

TO BE PROVIDED BY THE SUPERVISOR

This Question/Answer booklet for Sections 1 & 2.
A separate Question/Answer booklet for Section 3.
A separate Multiple Choice Answer sheet for Section 1.
A Chemistry Data Sheet.

TO BE PROVIDED BY THE CANDIDATE

Standard Items: Pens, pencils, eraser, ruler

Special Items: A calculator satisfying the conditions set by the Curriculum Council, and a '2B' pencil for the separate Multiple Choice Answer sheet.

IMPORTANT NOTE TO CANDIDATES

No other items may be taken into the examination room.

It is your responsibility to ensure that you do not have any unauthorised notes or other items of a non-personal nature in the examination room. Please check carefully, and if you have any unauthorised material with you, hand it to the supervisor **BEFORE** reading any further.

INSTRUCTIONS TO CANDIDATES

This paper consists of **THREE SECTIONS** as follows:

SECTION 1 contains **25 questions worth 2 marks each.** It is the multiple choice section.

Answer **ALL** questions in Section 1 on the Separate Multiple Choice Answer Sheet. Use a **'2B' PENCIL**. **DO NOT USE A BALL POINT OR INK PEN**. If you consider that two or more of the alternative answers are correct then select the BEST alternative. Marks will **NOT** be deducted for incorrect answers. This part is worth 50 marks and should take about 40 minutes.

Do not use pencil for Sections 2 & 3.

SECTION 2 contains **9 short answer questions**. You should answer **ALL** the questions. The answers are to be written in the spaces provided in this Examination booklet. This part is worth 74 marks and should take about 65 minutes.

SECTION 3 contains **5 extended response questions**. You should answer **ALL** the questions in detail in the **separate question/answer booklet provided.** This part is worth 89 marks and should take about 75 minutes. Express your answers in Section 3 to the appropriate number of significant figures,

At the end of the examination make sure that your **name** is on this Examination paper, the separate Question/Answer Booklet for Section 3 and your Multiple-Choice Answer Sheet.

SPECIAL INSTRUCTIONS

Chemical Equations

For full marks, chemical equations should refer only to those species consumed in the reaction and any new species produced. These species may be **ions** [for example $Ag^+(aq)$], **molecules** [for example $NH_3(g)$, $NH_3(aq)$, $CH_3COOH(l)$, $CH_3COOH(aq)$] or **solids** [for example $BaSO_4(s)$, $Cu(s)$, $Na_2CO_3(s)$].

Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time	Marks available	Percentage of exam	**Score**
Section One: Multiple-choice	25	25	40 min	50	23	
Section Two: Short answer	8	8	65 min	74	35	
Section Three: Extended answer	5	5	75 min	89	42	
			Total	**213**	**100**	
						%

Section One: Multiple-choice **23% (50 marks)**

This section has **25** questions. Answer **all** questions on the separate Multiple-choice Answer Sheet provided. For each question, shade the box to indicate your answer. Use a **'2B' PENCIL**. **DO NOT USE A BALL POINT OR INK PEN**. If you consider that two or more of the alternative answers are correct then select the BEST alternative. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

Suggested working time: 40 minutes.

Questions 1, 2 and 3 relate to the following equilibrium system.

Samples of $NO_3(g)$ and $NO_2(g)$ were injected into an empty flask and equilibrium was established according to the following equation.

$$NO_3(g) + NO_2(g) \rightleftharpoons N_2O_5(s) + \text{heat}$$

colourless *brown* *white*

1. While the system was establishing equilibrium, which of the following would **not** be observed?

   (a) The brown gas colour fades.
   (b) A white solid appears.
   (c) The pressure in the flask increases.
   (d) The temperature in the flask increases.

2. Which of the following conditions would increase the value of K for this equilibrium?

   (a) Decreasing the temperature of the system.
   (b) Increasing the temperature of the system.
   (c) Decreasing the volume of the system.
   (d) Increasing the volume of the system.

3. Which of the following conditions would favour a high equilibrium yield of $N_2O_5(s)$?

   (i) Increased concentrations of $NO_3(g)$ and $NO_2(g)$
   (ii) Increased volume of system
   (iii) Increased subdivision of $N_2O_5(s)$
   (iv) Increased temperature of system

   (a) (i) only.
   (b) (ii) only.
   (c) (i) and (iii) only.
   (d) (ii) and (iv) only.

Questions 4 and 5 refer to the equilibria associated with calcification.

Ocean acidification is a complex process which changes the chemistry of seawater and affects various marine organisms. Calcifying species use the $Ca^{2+}(aq)$ and $CO_3^{2-}(aq)$ in seawater to produce $CaCO_3(s)$, which then forms structures such as the shells or exoskeletons of marine organisms.

Two of the chemical equilibria associated with the process of calcification are shown below.

Equilibrium 1: $CO_2(g) + H_2O(l) + CO_3^{2-}(aq) \rightleftharpoons 2\ HCO_3^-(aq)$

Equilibrium 2: $Ca^{2+}(aq) + CO_3^{2-}(aq) \rightleftharpoons CaCO_3(s)$

4. State the effect of an increased $CO_2(g)$ concentration on the rate of each forward reaction.

	Equilibrium 1	**Equilibrium 2**
(a)	increased rate	decreased rate
(b)	increased rate	increased rate
(c)	decreased rate	increased rate
(d)	decreased rate	decreased rate

5. State the effect of an increased $CO_2(g)$ concentration on the equilibrium position of each reaction.

	Equilibrium 1	**Equilibrium 2**
(a)	reverse favoured	forward favoured
(b)	reverse favoured	reverse favoured
(c)	forward favoured	reverse favoured
(d)	forward favoured	forward favoured

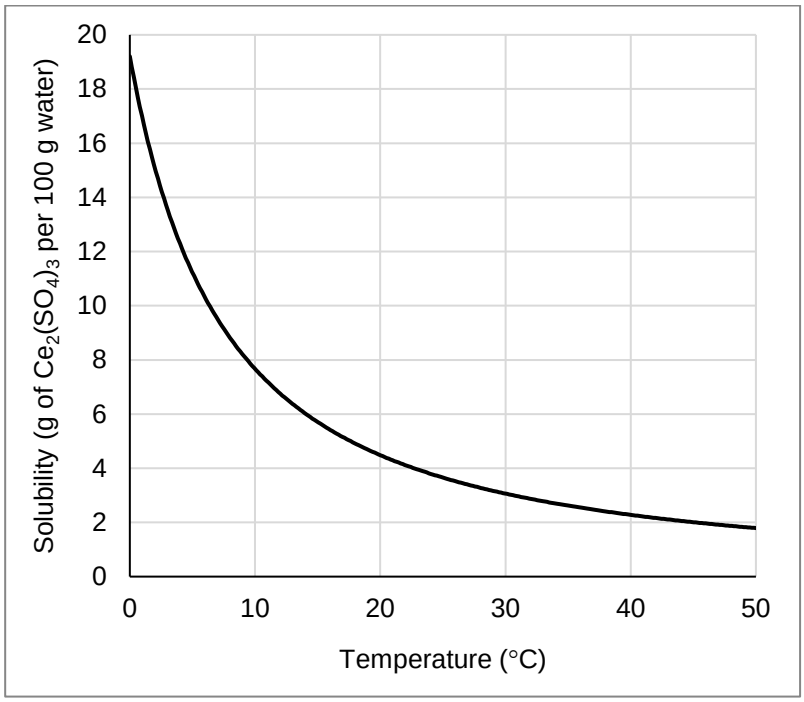
6. The endothermic autoionisation of water can be represented by the equation below.

$$H_2O(l) + H_2O(l) + \text{heat} \rightleftharpoons H_3O^+(aq) + OH^-(aq)$$

Distilled water at a temperature of 15 °C would have

(a) a concentration of hydronium ions greater than 1.0×10^{-7} mol L^{-1}.
(b) a concentration of hydroxide ions greater than 1.0×10^{-7} mol L^{-1}.
(c) a K_w value greater than 1.0×10^{-14}.
(d) a pH greater than 7.

7. Consider the following graph, which provides information regarding the solubility of cerium(III) sulfate, $Ce_2(SO_4)_3(s)$, at various temperatures.



An 8 g sample of $Ce_2(SO_4)_3(s)$ was added to a beaker containing 100 g of water at 20 °C. Equilibrium was established according to the following equation.

$$Ce_2(SO_4)_3(s) \rightleftharpoons 2\ Ce^{2+}(aq) + 3\ SO_4^{2-}(aq)$$

If the temperature of the system is decreased, which of the following is **not** correct?

(a) The conductivity of the solution would increase.
(b) The rate of dissociation would increase.
(c) The forward reaction would be favoured.
(d) The value of K would increase.

8. Consider the following equilibrium system.

$$6\ NOCl(g) + 237\ kJ \rightleftharpoons 6\ NO(g) + 3\ Cl_2(g)$$

A chemist wanted to;

- favour the reverse reaction
- decrease the rate of the reverse reaction
- maintain a constant K value

Which change should they impose on the system to satisfy all 3 criteria?

(a) Decrease the temperature of the system.
(b) Decrease the volume of the system.
(c) Remove some NOCl(g) from the system.
(d) Add some NO(g) to the system.

9. ‘Black powder’ is typically composed of solid potassium nitrate and charcoal dust (C_7H_4O). When this powder is ignited, the products formed are a mixture of solid potassium carbonate, carbon dioxide gas, water vapour and nitrogen gas.

Identify the element oxidised and reduced in this reaction.

	Oxidised	**Reduced**
(a)	N	K
(b)	C	N
(c)	O	N
(d)	C	H

10. Compare the four halogens in their elemental form; $F_2(g)$, $Cl_2(g)$, $Br_2(l)$ and $I_2(s)$. Which of the following statements is **correct**?

(a) $F_2(g)$ exists in the highest oxidation state.
(b) $Cl_2(g)$ is the strongest reducing agent (reductant).
(c) $Br_2(l)$ has the lowest tendency to gain electrons.
(d) $I_2(s)$ has the lowest reduction potential.

11. ‘Disproportionation’ refers to a redox reaction, where atoms of a particular element within a single species are simultaneously oxidised and reduced. Which of the following would **not** be regarded as a disproportionation reaction?

(a) $Cl_2(g) + 2\ OH^-(aq) \rightarrow ClO^-(aq) + Cl^-(aq) + H_2O(l)$
(b) $2\ H_2O_2(aq) \rightarrow 2\ H_2O(l) + O_2(g)$
(c) $NH_4NO_3(s) \rightarrow N_2O(g) + 2\ H_2O(g)$
(d) $2\ CuCl(s) \rightarrow CuCl_2(s) + Cu(s)$

12. When zinc metal is placed into a solution of 1 mol L^{-1} nitric acid, nitrogen dioxide gas is formed and the zinc metal dissolves.

Which redox equation **best** represents the reaction occurring?

(a) $Zn(s) + 2\ HNO_3(aq) + 2\ H^+(aq) \rightarrow Zn^{2+}(aq) + 2\ NO_2(g) + 2\ H_2O(l)$
(b) $Zn(s) + NO_3^-(aq) + 2\ H^+(aq) \rightarrow Zn^{2+}(aq) + NO_2(g) + 2\ H_2O(l)$
(c) $Zn(s) + 2\ NO_3^-(aq) + 4\ H^+(aq) \rightarrow Zn^{2+}(aq) + 2\ NO_2(g) + 2\ H_2O(l)$
(d) $Zn(s) + HNO_3(aq) + 3\ H^+(aq) \rightarrow Zn^{2+}(aq) + NO_2(g) + 2\ H_2O(l)$

Questions 13, 14 and 15 refer to the following information.

An electrochemical cell is set up with an unknown metal half–cell joined by a salt bridge to a hydrogen half–cell with a platinum electrode. Under standard conditions a voltage of between 0.7 and 0.8 V is produced.

13. Which one of the following metals is likely to be deposited at the cathode?

    (a) silver
    (b) platinum
    (c) zinc
    (d) iron

14. Which one of the following best describes what will be observed at the platinum anode?

    (a) Hydrogen ions will build up.
    (b) Bubbles of gas.
    (c) A build-up of a silver metal.
    (d) The anode will dissolve.

15. Which two of the following statements best explain the function of the salt bridge?

    The salt bridge
    (i) contains a non-reactive electrolyte solution.
    (ii) prevents direct contact between the oxidising and reducing agents.
    (iii) ions flow through the salt bridge towards the electrodes.
    (iv) prevents the build-up of charge on the electrodes.

    (a) i and ii only
    (b) ii and iii only
    (c) i and iv only
    (d) ii and iv only

Questions 16, 17 and 18 refer to metal corrosion.

Silver metal is particularly susceptible to a form of corrosion known as tarnishing. The chemical equation for this corrosion process is shown below.

Corrosion of silver: $4\ Ag(s) + 2\ H_2S(g) + O_2(g) \rightarrow 2\ Ag_2S(s) + 2\ H_2O(l)$

The corrosion of iron is a particularly damaging and expensive problem, due to the extensive use of iron in modern life. The chemical equation for this corrosion process is shown below.

Corrosion of iron: $4\ Fe(s) + 3\ O_2(g) + 2\ H_2O(l) \rightarrow 2\ Fe_2O_3.H_2O(s)$

16. Select the option which correctly identifies the change in oxidation number of each element involved in the process of silver corrosion.

	Ag	**H**	**S**	**O**
(a)	(0) to (+1)	no change	no change	(0) to (-2)
(b)	no change	(0) to (+1)	no change	(0) to (-2)
(c)	(0) to (+2)	no change	(-2) to (-4)	no change
(d)	(0) to (+1)	no change	(-2) to (-4)	no change

17. Select the statement that is **not** common to both the corrosion of silver **and** the corrosion of iron.

(a) The metal is the anodic site.
(b) Oxygen gas is the oxidising agent.
(c) The metallic element forms a compound.
(d) A thin layer of metallic oxide forms on the metals.

18. Which one of the following could slow the corrosion of a small strip of iron?

(a) attaching a piece of tin to the iron
(b) attaching a piece of copper to the iron
(c) attaching a piece of zinc to the iron
(d) storing the iron under water

Questions 19 and 20 refer to the following information.

The reaction between magnesium metal and water occurs very slowly in cold water.
The balanced chemical equation is shown below. The reaction is much faster with steam (water vapour > 100 °C).

$$Mg(s) + 2\,H_2O(\ell) \rightarrow Mg(OH)_2(s) + H_2(g)$$

19. Which one of the following is the E° value for this reaction?

(a) +3.19 V
(b) –1.53 V
(c) +1.53 V
(d) +0.35 V

20. The reaction is exothermic but in order for magnesium to react with steam the magnesium is first ignited in a hot flame. Which one of these is the likely reason for the magnesium being ignited first?

In the reaction between magnesium and steam

(a) the enthalpy of reactants is higher than products.
(b) the activation energy is low.
(c) the activation energy is high.
(d) heat must be gained from the surroundings.

21. Four beakers (A, B, C and D) were placed on a laboratory bench, each containing distilled water and several drops of universal indicator. A small sample of a different salt was then dissolved into each beaker, according to the table below.

Beaker A	**Beaker B**	**Beaker C**	**Beaker D**
+ $NH_4NO_3(s)$	+ $MgF_2(s)$	+ $KCH_3COO(s)$	+ $Na_3PO_4(s)$

The colour of the solution in beaker

(a) A would change from green to blue.
(b) B would change from green to yellow.
(c) C would change from green to orange.
(d) D would change from green to purple.

22. Consider the equations below.

$$H_2CO_3(aq) + H_2O(\ell) \rightleftharpoons HCO_3^-(aq) + H_3O^+(aq)$$
$$HCO_3^-(aq) + H_2O(\ell) \rightleftharpoons CO_3^{2-}(aq) + H_3O^+(aq)$$

Which one of the following species is the conjugate base of HCO_3^-?

(a) H_2O
(b) CO_3^{2-}
(c) H_3O^+
(d) H_2CO_3

23. Which two of the following pairs of solutions could form buffers?

(i) $HC\ell/C\ell^-$
(ii) $NH_3/HC\ell$
(iii) H_2SO_4/HSO_4^-
(iv) CH_3COOH/CH_3COO^-

(a) i and ii only
(b) ii and iii only
(c) iii and iv only
(d) ii and iv only

24. Which of the following pieces of equipment should be rinsed with the relevant chemical solution, rather than just distilled water, before using in an acid – base titration?

(i) burette
(ii) conical flask
(iii) pipette
(iv) volumetric flask

(a) i only
(b) i and iii only
(c) i, iii and iv only
(d) i, ii and iv only

25. The overall equation for the discharge reaction of a lead acid car battery is shown below.

$$Pb(s) + PbO_2(s) + 4\,H^+(aq) + 2\,SO_4^{2-}(aq) \rightarrow 2\,PbSO_4(s) + 2\,H_2O(\ell)$$

Which species is the oxidising agent?

(a) Pb
(b) PbO_2
(c) $PbSO_4$
(d) H^+

End of Section One

Section Two: Short answer **35% (74 marks)**

This section has **9** questions. Answer **all** questions. Write your answers in the spaces provided.

When calculating numerical answers, show your working or reasoning clearly. Express numerical answers to the appropriate number of significant figures and include appropriate units where applicable.

Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.

- Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
- Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

Suggested working time: 65 minutes.

Question 26 **(6 marks)**

Consider the following chemical experiments. Describe the reactants and also the contents of the flask at the end of the experiment.

(a) A small piece of copper metal is placed in an excess of iron(II) sulfate solution. (2 marks)

(b) A large piece of cobalt metal is placed in a small volume of 2.00 mol L^{-1} hydrochloric acid. (2 marks)

(c) Solutions of silver nitrate and sodium chloride are mixed. (2 marks)

Question 27 **(10 marks)**

In 1826 when many of the elements of the periodic table were yet to be discovered, a scientist added aqueous chlorine ($C\ell_2(aq)$) to the solid residue left after evaporating sea water. This yielded a pungent smelling orange solution. After further testing he concluded it was a new element.

Part of the material safety data sheet for chlorine is reproduced below

SAFETY DATA SHEET–Chlorine

Hazards identification :

OXIDIZING GASES - Category 1
GASES UNDER PRESSURE - Compressed gas
ACUTE TOXICITY (inhalation) - Category 2
SKIN CORROSION/IRRITATION - Category 1
SERIOUS EYE DAMAGE/ EYE IRRITATION - Category 1
AQUATIC HAZARD (ACUTE) - Category 1
AQUATIC HAZARD (LONG-TERM) - Category 1

Signal word :

Danger

Hazard statements :

May cause or intensify fire; oxidizer.
Contains gas under pressure; may explode if heated.
Fatal if inhaled.
Causes severe skin burns and eye damage.
Very toxic to aquatic life with long lasting effects.

(a) Write a balanced redox equation for the reaction between chlorine and the likely species present in the salt residue which produced the new element. (2 marks)

At the time the experiment was done the chemicals in the salt residue were unknown as were the nature of any of the products of the reaction with chlorine.

(b) State two safety precautions you would take if you were to repeat the experiment.

(2 marks)

1 _____

2 _____

Question 27 (continued)

Chlorine gas is a stronger oxidising agent than solid iodine.

(c) Explain this statement with the aid of suitable half equations and standard reduction potentials. (3 marks)

(d) Write three observations for the reaction when excess aqueous chlorine ($C\ell_2(aq)$) is slowly added to a potassium iodide solution (KI(aq)).

(3 marks)

1

2

3

Question 28 **(8 marks)**

Calculate the final pH of a solution made by dissolving 1.54g NaOH(s) in 100.0 mL of 0.100 mol L^{-1} H_2SO_4(aq). Assume no volume change.

Question 29 **(6 marks)**

Permanganic acid ($HMnO_4$) can be found as an unstable red-violet solution which decomposes at temperatures above 40 °C.

It can be made by mixing a solution containing manganese(II) ions with powdered lead dioxide, PbO_2, in the presence of sulfuric acid. This suspension is then stirred. The reaction produces permanganic acid and a precipitate of lead(II) sulfate.

Write oxidation and reduction half-equations and an overall redox equation for this reaction.
You may assume the sulfuric acid is present entirely as $H^+(aq)$ and $SO_4^{2-}(aq)$.

Oxidation half-equation	
Reduction half-equation	
Overall redox equation	

Question 30 **(7 marks)**

Potassium hydrogen iodate, $KH(IO_3)_2$, can be used as a primary standard in acid-base titrations, providing the percentage purity of the solid is known.

An 8.435 g sample of **impure** $KH(IO_3)_2(s)$ was dissolved in distilled water, transferred to a volumetric flask and made up to 500.0 mL. Then 25.00 mL aliquots of this solution were titrated against standardised 0.05084 mol L^{-1} NaOH(aq). An average titre of 20.70 mL was required to reach the equivalence point.

The chemical equation for the titration reaction that occurred is given below.

$$KH(IO_3)_2(aq) + NaOH(aq) \rightarrow KNa(IO_3)_2(aq) + H_2O(l)$$

Calculate the percentage purity of the $KH(IO_3)_2(s)$ that was used in this experiment.

Question 31 **(8 marks)**

Consider the following reaction that has been allowed to establish equilibrium.

$$2\ OH^-(aq) + Cl_2(g) \rightleftharpoons Cl^-(aq) + ClO^-(aq) + H_2O(l)$$

The following table considers the effects of imposing different changes upon this system.

(a) Complete the following table by predicting which direction would be favoured, as well as the resulting effect on the concentration of $ClO^-(aq)$ when compared with the original equilibrium. Consider each of the imposed changes in isolation.

Imposed change	**Favoured direction** (forward, reverse, no shift)	**Effect on final concentration of ClO^- (aq)** (increase, decrease, no change)
A small amount of NaClO(s) was added		
The volume of the canister was decreased		
Distilled water was added		
Several drops of 2 mol L^{-1} $Mg(NO_3)_2(aq)$ was added		

Question 32 **(10 marks)**

A water tank contained 25.0 kL of contaminated water with a pH of 10.1. A chemist decided to add some solid acetylsalicylic acid crystals to the water tank, to lower the pH. Acetylsalicylic acid is a monoprotic acid with the formula $C_9H_8O_4$ (M = 180.158 g mol^{-1}).

Calculate the mass of acetylsalicylic acid crystals that should be added to the tank and dissolved in the water, to lower the pH to 7.8.

Question 33 **(9 marks)**

A chemistry class was given four (4) jars labelled A, B, C and D.

Each jar contained small pieces of a silver-coloured metal. The teacher informed the students that the metals were tin, cobalt, cadmium and nickel.

The students were asked to design an investigation that would determine the identity of the metal in each jar.

The students set up 4 test tubes, each containing 5 mL of 1.0 mol L^{-1} lead(II) nitrate solution, $Pb(NO_3)_2(aq)$. A piece of each different metal was then added to each test tube. The students' observations are recorded in the table below.

	Observations
$Pb(NO_3)_2(aq)$ + metal A	A silver metal dissolves in a colourless solution. A new grey solid and a green solution are produced.
$Pb(NO_3)_2(aq)$ + metal B	A silver metal dissolves in a colourless solution. A new grey solid is produced. Solution remains colourless.
$Pb(NO_3)_2(aq)$ + metal C	A silver metal dissolves in a colourless solution. A new grey solid is produced. Solution remains colourless.
$Pb(NO_3)_2(aq)$ + metal D	A silver metal dissolves in a colourless solution. A new grey solid and a pink solution are produced.

(a) Identify metals A and D. (2 marks)

A	
D	

To distinguish between metals B and C, one student suggested adding a piece of each to separate solutions of aqueous nickel bromide, $NiBr_2(aq)$.

(b) Justify how this would allow metals B and C to be distinguished. Include observations for both samples and a relevant chemical equation in your answer.

(5 marks)

(c) Using the results of this investigation, how would the students be able to identify which of the metals (A, B, C or D) was the strongest reducing agent (reductant)?

(2 marks)

Question 34 **(10 marks)**

On a table of standard reduction potentials, the 'hydrogen half-cell' or 'standard hydrogen electrode' is designated an EMF of 0 V. The standard hydrogen half-cell is set up using a platinum electrode, hydrogen gas (H_2) and a solution containing hydrogen ions (H^+).

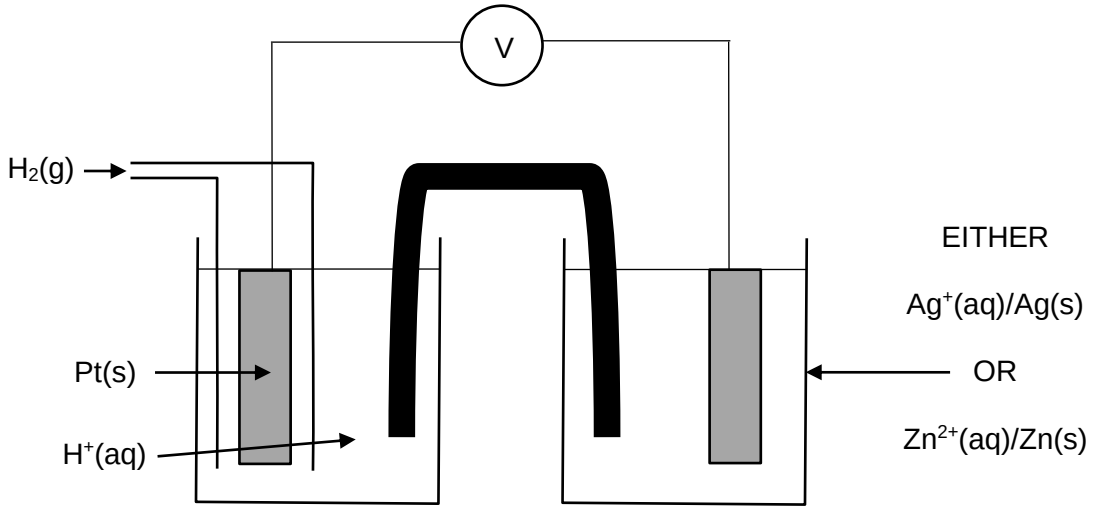
(a) State the values that would be used when setting up the hydrogen half-cell under standard conditions. (2 marks)

Partial pressure of $H_2(g)$	
Concentration of $H^+(aq)$	

A standard hydrogen half-cell was joined by wires and a salt bridge to a second half-cell. Two different experiments were performed;

- In Experiment 1, the $Ag^+(aq)/Ag(s)$ half-cell was used.
- In Experiment 2, the $Zn^{2+}(aq)/Zn(s)$ half-cell was used.

A diagram of the experimental set up is shown below. Assume all half-cells were set up under standard conditions.



(b) In which experiment would the greater EMF have been produced? State the value of this EMF. (2 marks)

_____

_____

(c) Discuss how the role of the hydrogen half-cell differs in Experiment 1 and 2. Include a relevant half-equation for the hydrogen half-cell in each case.

(6 marks)

END OF SECTION TWO

Spare answer page

Question number: _____

Spare answer page

Question number: _____

Spare answer page

Question number: _____

Hale School
Semester One
Examination, 2020

Write your name below:

Yr12 ATAR CHEMISTRY UNIT 3

Circle your teacher's initials:

JWZ PRB KF AD

For Examiners only	
Part 3	

Section 3 Question and Answer Booklet

Section Three: Extended answer **42% (89 marks)**

This section contains **five (5)** questions. You must answer **all** questions. Write your answers in the spaces provided below.

Where questions require an explanation and/or description, marks are awarded for the relevant chemical content and also for coherence and clarity of expression. Lists or dot points are unlikely to gain full marks.

Final answers to calculations should be expressed to the appropriate number of significant figures.

Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.

- Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
- Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

Suggested working time: 75 minutes.

See Next Page

Question 35 **(18 marks)**

Silver metal can be extracted from the ore 'argentite' which contains the compound $Ag_2S(s)$. In the first step of this extraction process, the ore containing $Ag_2S(s)$ is crushed, and then a solution of sodium cyanide, NaCN(aq), is added to leach the silver out of the ore. This forms the complex ion sodium argentocyanide, $Na[Ag(CN)_2](aq)$, as shown in the equation below.

$$Ag_2S(s) + 4\ NaCN(aq) \rightleftharpoons 2\ Na[Ag(CN)_2](aq) + Na_2S(aq)$$

(a) Write the equilibrium constant expression for this reaction. (1 mark)

If 12.5 kL of 5.0 g L^{-1} NaCN(aq) was added to the leaching tank and poured over the crushed ore;

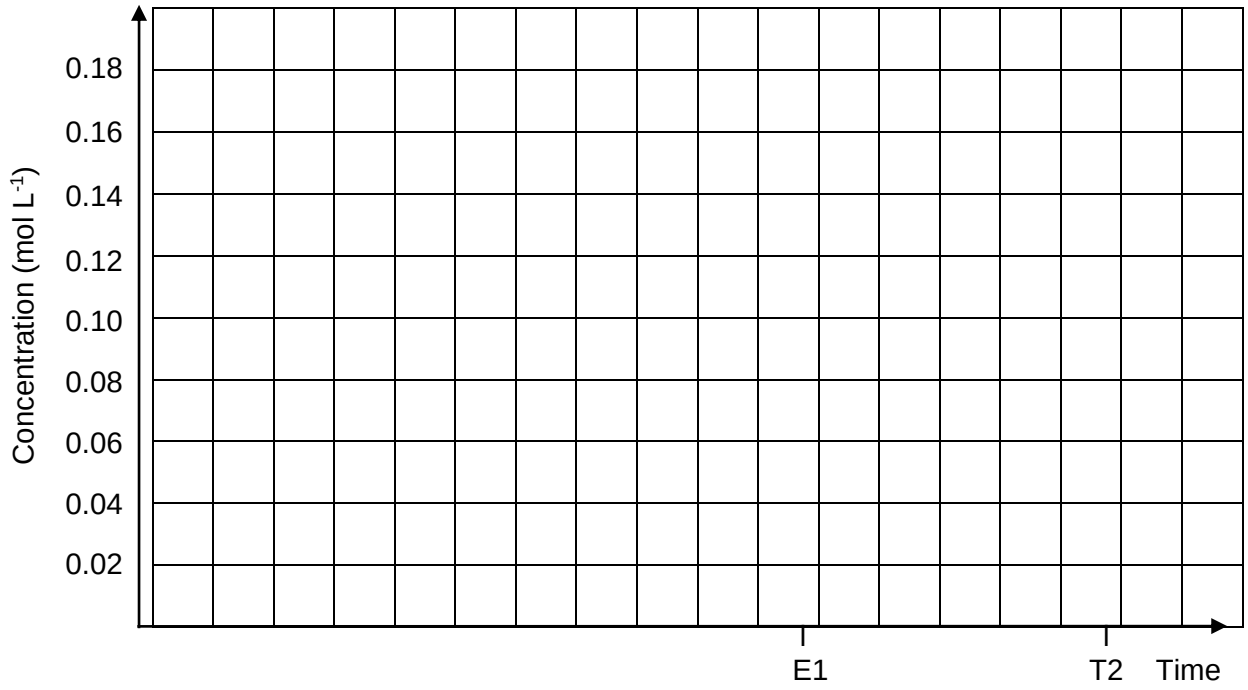
(b) Calculate the maximum mass of $Ag_2S(s)$ that could react. (4 marks)

See Next Page

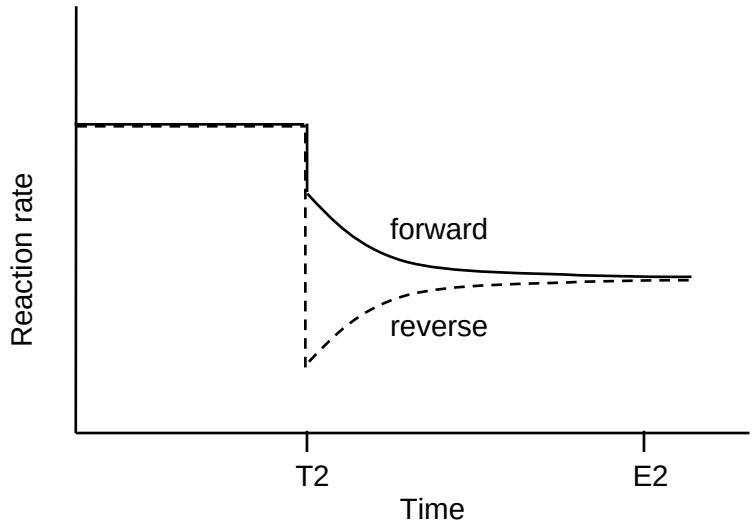
(c) Explain, in terms of the collision theory, why the ore is crushed before mixing with the NaCN(aq) solution. (3 marks)

A particular leach tank contained an excess mass of crushed argentite ore containing $Ag_2S(s)$. A 0.16 mol L^{-1} solution of NaCN(aq) was poured over the ore, and the reactants were mixed. At Time E1, equilibrium was established. The concentration of the NaCN(aq) was measured again and found to be 0.04 mol L^{-1}.

(d) On the axes below, sketch curves showing the concentration of all relevant species, from Time 0 until the establishment of equilibrium at Time E1. Continue your curves from Time E1 to Time T2. Label each curve. (5 marks)



At Time T2, a temperature change is imposed on the system. The following rate graph was drawn to illustrate the effects of this imposed change.



(e) State whether the temperature was increased or decreased at Time T2. (1 mark)

(f) Justify, using the information provided in the rate graph above, whether the forward reaction is endothermic or exothermic. (4 marks)

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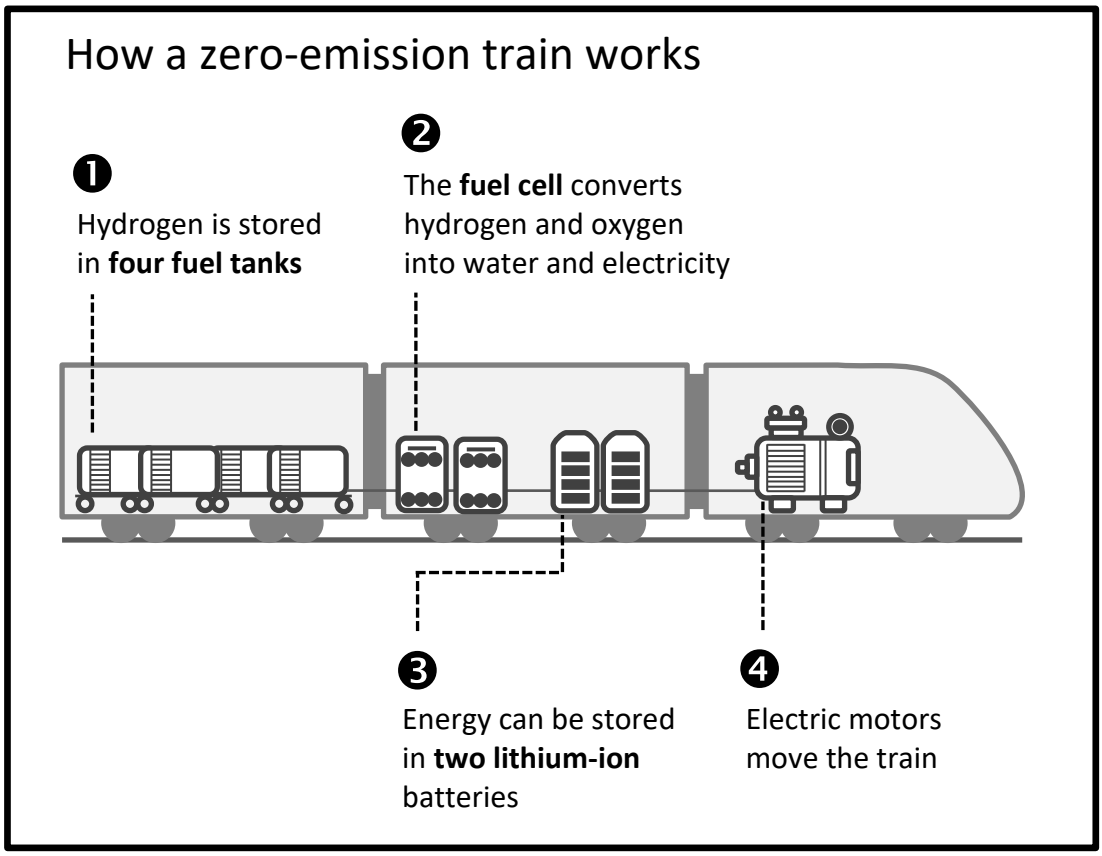
Question 36 **(18 marks)**

The 'Hydroflex' train was launched in the United Kingdom last year, as Britain's first hydrogen-fuelled train. The technology is currently being trialled, but the government is hoping that hydrogen trains will be in common use by 2022, and that all diesel trains will be removed from use by 2040.

The diagram below provides some information about how the hydrogen train works.



The fuel cell used is more specifically described as a 'polymer electrolyte membrane' (or PEM) fuel cell stack. These cells function at a temperature of around 50-100 °C. The electrolyte is a water-based acidic polymer membrane.

(a) Write oxidation and reduction half-equations and an overall equation to represent the reaction occurring in the PEM fuel cell. Calculate the EMF produced under standard conditions. (4 marks)

Reduction half-equation	
Oxidation half-equation	
Overall equation	
EMF under standard conditions	

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The PEM is also often called a ‘proton-exchange membrane’ because one of its main functions is to conduct protons from one half-cell to another. The design of the PEM is instrumental in the function of the fuel cell. As well as conducting protons it has to;

- separate the two half-reactions
- prevent hydrogen and oxygen gas crossover
- allow the conduction of protons but not the conduction of electrons
- resist degradation from the surrounding environment.

(b) At which electrode are protons produced? Justify your answer. (2 marks)

(c) Why must the PEM have the ability to conduct protons but **not** electrons? (2 marks)

As shown in the diagram on the previous page, the hydrogen train also contains lithium-ion batteries. These are similar in design to those used in electric vehicles, mobile phones and other portable devices.

The chemistry of lithium-ion cells is quite complex, but in general, relies on the transfer of lithium ions between electrodes. The relevant half-equations for a lithium-ion battery are given below.

Cathode: $CoO_2 + Li^+ + e^- \rightarrow LiCoO_2$

Anode: $LiC_6 \rightarrow C_6 + Li^+ + e^-$

(d) Justify why fuel cells and lithium-ion batteries can both be classified as ‘galvanic’ cells. (2 marks)

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(e) Classify the lithium-ion battery as a ‘primary’ or ‘secondary’ cell. Justify your choice using the information provided. (2 marks)

One of the main advantages of replacing current diesel-powered trains with hydrogen trains is to reduce carbon dioxide emissions. The increase in atmospheric $CO_2(g)$ is a primary cause of global warming, but can also lead to other negative environmental consequences such as ocean acidification.

(f) Describe, using relevant chemical equations, how an increase in atmospheric $CO_2(g)$ has led to a decrease in the pH of our oceans.

(6 marks)

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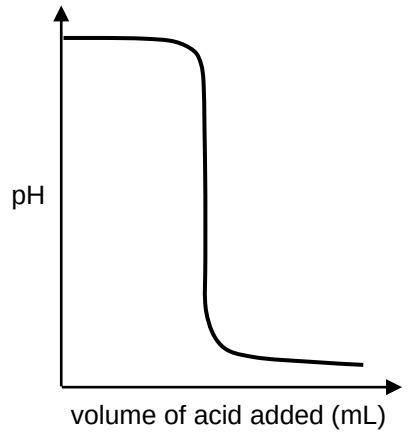
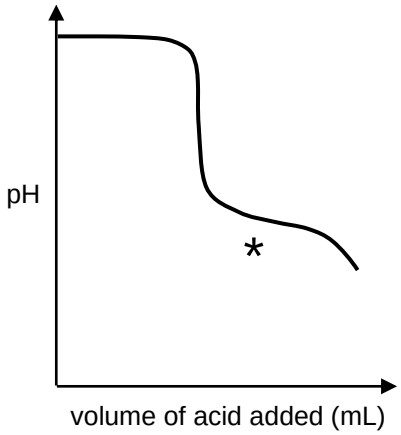
Question 37 **(18 marks)**

A group of chemistry students were comparing and contrasting two different acid-base titrations. They set up 'Titration A' and 'Titration B' as follows;

	Titration A	**Titration B**
Substance in conical flask	20.00 mL of 0.10 mol L^{-1} NaOH(aq)	20.00 mL of 0.10 mol L^{-1} NaOH(aq)
Substance in burette	0.10 mol L^{-1} HCl(aq)	0.10 mol L^{-1} CH_3COOH(aq)
Sketch of titration curve		

(a) In the table above, label the equivalence point on **both** titration curves. (2 marks)

(b) State the pH at the equivalence point in Titration A. Justify your answer. (3 marks)

(c) In Titration A, state the volume of HCl(aq) that would have been added from the burette to reach the equivalence point. (Note that a calculation is not required.) (1 mark)

(d) Would the volume of $CH_3COOH(aq)$ required to reach the equivalence point in Titration B be higher, lower or equal to the volume of HCl(aq) required in Titration A? Circle your choice below, and briefly justify your answer. (2 marks)

higher lower equal

The students decided to investigate Titration A in more detail. Once they had successfully reached the equivalence point, they added 5 extra drops of HCl(aq).

(e) Calculate the pH of the resulting solution within the conical flask. Assume the volume of 1 drop is equal to 0.05 mL. (5 marks)

As can be seen in the curve for Titration B, if extra $CH_3COOH(aq)$ is added after the equivalence point has been reached, the change in pH is much less pronounced. In fact, the addition of 5 extra drops of $CH_3COOH(aq)$ lowers the pH by much less than 2 units.

(f) Complete the table below, by listing the next two **compounds** with highest concentration (after water) that would be present in the conical flask for Titration B, when 5 drops of $CH_3COOH(aq)$ has been added past the equivalence point. (2 marks)

Titration A	**Titration B**
1. $H_2O(l)$	1. $H_2O(l)$
2. $NaCl(aq)$	2.
3. $HCl(aq)$	3.

Further addition of $CH_3COOH(aq)$ past the equivalence point (the region indicated by $\star$ on the titration curve) continues to cause a much smaller change in pH, compared to Titration A.

(g) Justify why, upon addition of excess acid after equivalence, the change in pH in Titration B occurs to a much lesser degree than in Titration A. (3 marks)

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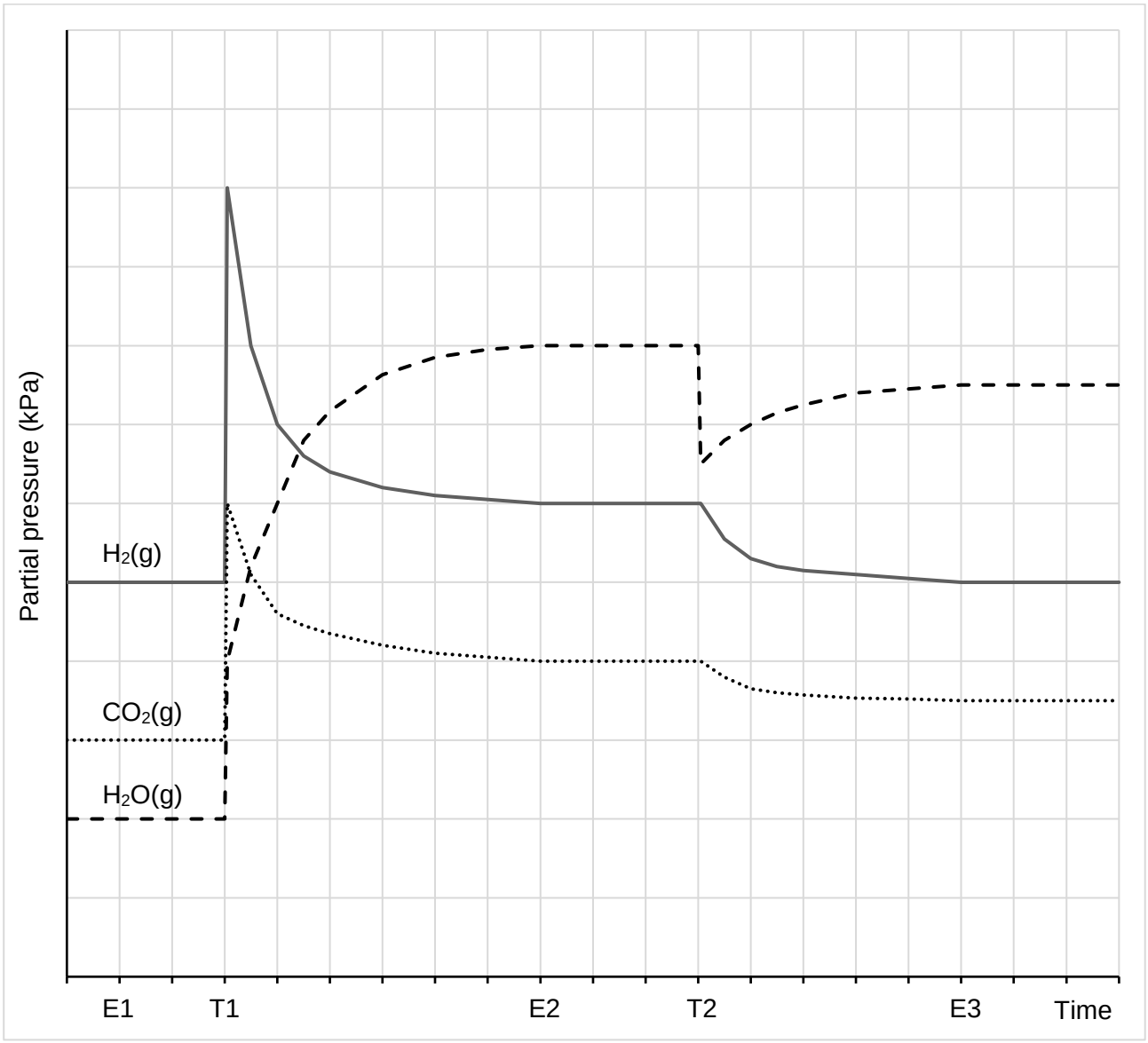
Question 38 **(18 marks)**

The Bosch reaction has applications in space travel and is utilised aboard space shuttles, since it is able to remove carbon dioxide from the air and generate clean water in the process. The reaction requires a metallic catalyst such as iron, cobalt or nickel. The equation for the Bosch reaction is given below.

$$CO_2(g) + 2\,H_2(g) \rightleftharpoons 2\,H_2O(g) + C(s) + 90.13\ kJ$$

Consider a reaction chamber, where the Bosch reaction has been allowed to establish equilibrium. The graph below shows the effect of imposing different changes on the system.



(a) State the change imposed on the system at Time T1. (1 mark)

_____

_____

(b) Explain, in terms of the collision theory, the effect of the imposed change at Time T1 on the position of equilibrium. (4 marks)

(c) State the change imposed on the system at Time T2, as well as the effect this change has on the position of equilibrium. (2 marks)

(d) Complete the table below, regarding the changes that would be observed in reaction rate in response to the change imposed at Time T2. In each box of the table, write either 'increased', 'decreased' or 'no change'. Your answers should be stated in comparison to the previous equilibrium that had been established at Time E2. (4 marks)

	Immediate change in rate (increase / decrease / no change)	**Final / overall change in rate** (increase / decrease / no change)
Forward reaction		
Reverse reaction		

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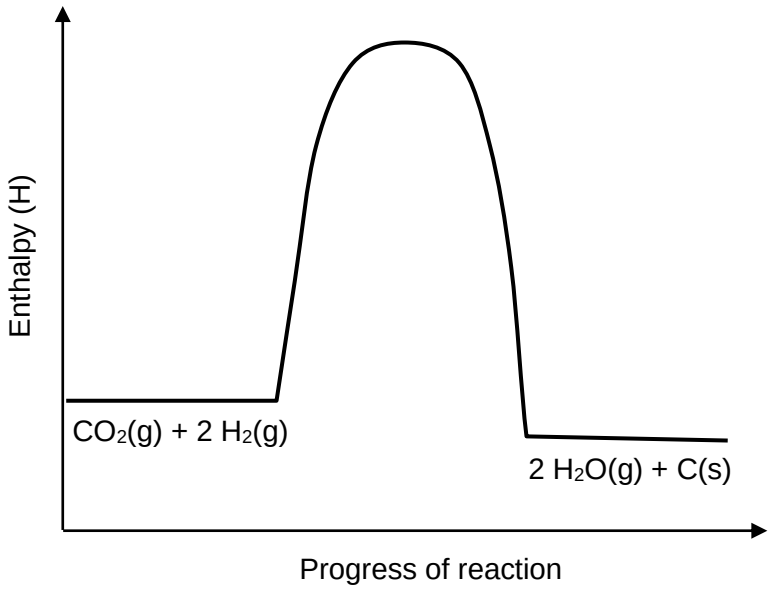
The energy profile diagram for the Bosch reaction is shown below. The reaction has a very high activation energy and must be carried out at a temperature greater than 450 °C. It is only mildly exothermic.



(e) Comment on the likely reversibility of this reaction. (2 marks)

(f) Add to the energy profile diagram above, by indicating the effect of including metallic iron in the reaction system. (1 mark)

(g) Explain, in terms of the collision theory, the role of the iron in this reaction. (4 marks)

Question 35 **(17 marks)**

Titratable acidity in wine is a commonly performed technique carried out during winemaking. Acid content in wine affects its colour, balance of flavour and taste. Several acids can be present in wine including tartaric, malic and citric acid but acid content in wine is reported as percentage tartaric acid (a diprotic acid).

The titration can be performed using previously standardised sodium hydroxide solution with phenolphthalein as the end point indicator. The equivalence point of this reaction occurs at pH 8.2.

(a) Explain, in terms of the equivalence point and end point, why phenolphthalein is a suitable indicator for this reaction. State the colour change observed. (4 marks)

(b) State three reasons why the sodium hydroxide solution must be standardised before use. (3 marks)

1 _____

_____

2 _____

_____

3 _____

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Generally the titration is carried out using a pH meter, rather than phenolphthalein, as the result is "less prone to human error".

(c) Explain why using a pH meter is a preferred method to minimise random error. (2 marks)

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A pH meter must be calibrated before use with known buffer solutions, usually pH 4.00 and 7.00. A pH 4.00 buffer can be made by dissolving 8.954 g of $Na_2HPO_4.12H_2O$ and 3.4023 g KH_2PO_4 in distilled water and making the volume up to exactly 1.000 L.

(d) Write the chemical reaction for this buffer using the HPO_4^{2-} and $H_2PO_4^-$ ions.

(2 marks)

(e) Calculate the molar concentration of the $Na_2HPO_4.12H_2O$ in the buffer to the appropriate number of significant figures.

(4 marks)

(f) Define 'buffering capacity'. (2 marks)

End of questions

Supplementary page

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Supplementary page

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